

Research Memorandum 77-4



A SURVEY OF SOME HUMAN FACTOR PROBLEMS IN NIGHT OPERATIONS

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Donald O. Weitzman

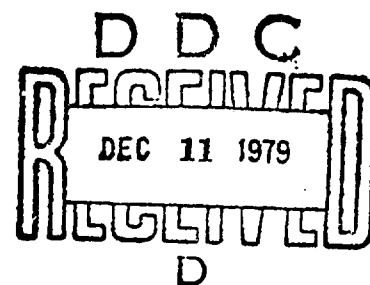
Halim Ozkaptan, Work Unit Leader

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HUMAN FACTORS IN TACTICAL OPERATIONS TECHNICAL AREA



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August 1977

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A SURVEY OF SOME HUMAN FACTOR PROBLEMS IN NIGHT OPERATIONS

I. INTRODUCTION.

Swarms of Soviet tanks under an umbrella of fighter-bombers pouring into Western Europe to be met by NATO tanks, guns, and aircraft has been the western military conception of a major conventional war. This picture is likely to change dramatically as a result of the development of precision-guided weapons, remotely controlled unmanned aircraft, high-energy laser beams, and other advanced technology weaponry.

Military doctrine is being reexamined and in some instances revised, as a result of large-scale deployment of new weapons by the Soviet Union and its chief allies in the Warsaw Pact, and by the United States, Britain, France, and West Germany. The new arms with their increasing accuracy, range, and deadliness have altered conventional military wisdom. Some tentative conclusions about these and other new weapon systems on future tactics are emerging.

One conclusion is that the new weapons probably will restrict the freedom of operation of the combat arms. It is axiomatic that with these new weapons, what can be seen by remote sensors or by the eye, can be hit, and what can be hit probably will be destroyed.

Consequently, concentrations of men or weapons are highly dangerous; there must be greater emphasis on concealment through camouflage, smoke-screens, and night operations for armor, artillery, and infantry. Clearly the usefulness of almost all the new weapons at night is sharply reduced.

Another conclusion is that with increased probability of destruction, military doctrine will stress nighttime access to the battlefield. With new precision-guided weapons, units of only three or four men, on foot or in jeeps, can affect the battle. Such units, dispersed and operating under nighttime conditions, would be in a position to blunt hostile armored attacks.

Several students of the new weapon technology have stressed that the changing conditions of war will tend to make military night operations much more common in the future. In that spirit, we have formulated a brief description of the behavioral problems in military night operations as they may apply to operational settings. The descriptions were derived, some directly and others inferentially, from military sources dealing with the problems of night operations.

The presentation of the material in this report, however, reflects our perception of the importance of the topics discussed. Thus the problem of night mobility is viewed as primary with night vision an important interacting factor. The brief treatment of stress as related to night operations is less a reflection of importance than it is of a relative paucity of data to report.

II. THE PROBLEM

Military operations and current tactical doctrine emphasize the importance of both night and day operations. The advantage of a 24-hour capability for the soldier emphasizes the importance of studies in night operations and the behavioral skills--sensory, motor, and cognitive--that underlie successful performance.

Military night operations basically depend upon the ability of the individual soldier to accomplish successfully his assigned task. In recent years, emphasis has been placed on the development of devices that externally aid night vision capability. The use of such devices under reduced illumination has extended the concept of continuous military operations.

However, in spite of such devices, it is difficult to provide visual cues through the instruments to the point where the devices have the full force of direct vision. There are many other aspects of military night operations that go beyond an individual's night vision capabilities.

The soldier's capacity to operate at night is severely restricted. It depends on the individual's level of training, but also includes other biological and behavioral components. Operating at night requires that the individual soldier be thoroughly familiar with the operational environment.

A soldier must be able to find his way and maintain a direction of movement, be able to detect, locate, and identify targets from sensory information, and be able to maintain efficiency under stress and during extended operations. Yet, even among soldiers trained in night operations, the ability to perform these tasks shows wide variation. Thus the concept of continuous and sustained night operations suggests an evaluation of the importance of a wide range of human factors in night operation.

For this reason, the principal concerns of this report are: (a) to identify those behavioral problems peculiar to the military during night operations, (b) to review the state of knowledge on the behavioral or human factor aspects of military night operations, and (c) to suggest guidelines for future research leading to a better understanding of the behavioral skills as they relate to night operations performance in the individual soldier.

III. SCOPE OF THE REPORT

→ In the preliminary research on this subject, the physical, biological, and behavioral factors that affect night operation performance in the individual soldier were considered. Subjects such as silent movement and camouflage, communication at night, and night target engagement constitute an important but separate body of knowledge and are not part of this plan.

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Emphasis in this report has been placed on current sensory, motor and cognitive factors in night mobility, the role of night vision, and the effect of fatigue and stress in night operations. In addition, individual differences in otherwise similar populations exposed to similar environmental conditions are considered.

This report provides background information potentially useful in planning future behavioral research on efficient utilization of the individual soldier during continuous and sustained night operations. Also considered in this light are the further evolution of night operations training, and the military operations that require weighing of the variability and limitations of the night warfare capability of a soldier.

IV. REVIEW DISCUSSIONS.

A. Introduction.

The review discussions represent a comprehensive evaluation of the state of knowledge on human factors and night operations. Emphasis has been given to recent research findings which bear on the problems of night mobility (e.g., navigation), night vision, fatigue, and stress. Because these aspects encompass only a small portion of the subject of military night operations, it is appropriate to characterize briefly some tentative conclusions that have already emerged within the military context concerning human factors in night operations:

1. Insufficient time is devoted to training individual soldiers and units for night operations.
2. Insufficient data is available on the problems relating to human endurance in continuous military operations.
3. Performance measures useful for evaluating the individual soldier and units during night operations training are not readily available.
4. The soldier who is more effective in navigating during daytime is also more effective at night.
5. The soldier who is best able to travel safely at night (e.g., detecting and avoiding obstacles, dropoffs, etc.) is not necessarily the best in navigating at night.
6. The ability to navigate, particularly at night, depends on the ability of the soldier to conceptualize or maintain a fairly accurate representation of the terrain on which he must operate. The ability to form a topographical representation of the terrain involves a subset of skills, namely, the ability to read a map, analyze terrain, and visualize in his mind's eye an analogue representation of terrain.

7. To navigate effectively at night also requires an ability to estimate distance between points.
8. There are distinct individual variations in the ability to navigate accurately or to travel safely at night which appear independent of military training.
9. Night vision, aided or unaided, is important for detecting and recognizing targets. Night vision generally is considered not very useful in helping the soldier maintain his bearings or to maintain a direction of movement.

B. Night Navigation (Mobility).

1. Introduction.

Night mobility for the soldier involves the ability to travel accurately, safely, and quietly (i.e., stealthily) under low visibility. It is plausible to assume that mobility in military night operations involves all three uncorrelated skills and that these skills can be taught. Accurate travel refers to the ability to maintain a direction for a given distance between landmarks (i.e., dead reckoning).

The complex art of dead reckoning takes many different forms and probably involves a different complex of sense modalities, movements, and conceptual skills. The aptitude depends, in part, on the ability to read a map, utilize a compass, analyze terrain, relate map and terrain features, and maintain a "sense of direction."

For night mobility in particular, the soldier must be able to memorize the details of terrain and landmarks shown on a map. Safe movement at night involves the detection and avoidance of obstacles and dropoffs which may cause injury. Finally, stealth involves a combination of silent movement, unobserved movement, and camouflage.

An individual soldier's ability and confidence to operate at night can be enhanced by training in all these skills. There are, however, wide individual differences in that ability. Some men develop satisfactory night movement skills, but many do not. Those that do are often unable to specify their particular skill or communicate them to others.

This is not to suggest that these skills are innate, but only to indicate how excruciatingly difficult it is to make those skills explicit. Nevertheless, the concept of continuous day and night operations suggests a reevaluation of the importance of individual variation in navigation and mobility skills.

The reader may surmise that selection of individuals with superior skills, in addition to training to enhance those skills, can be employed to meet military requirements better for night operations.

There is much to learn of human factors before night operation doctrine can be formulated and tested effectively. The Army must learn how to measure significant aspects of total mobility performance for a variety of military tasks in order to gauge the contribution of a wide variety of factors to that performance. The Army should assess more effectively those individual differences that influence mobility performance, both at night and during the day.

A desirable piece of knowledge, for example, would be to know the origin and magnitude of these differences and how they influence an individual's performance. But first, the Army must arrive at a clearer statement of the perceptual factors--sensory, motor, and conceptual--that underlie successful mobility. Knowledge of this sort will reveal what to train for and what information to provide with the mobility aids we construct.

Apparently, accurate night movement for the individual soldier will depend in part on non-visual senses. In daylight conditions, the soldier may obtain quick and precise information about the nature of the land through which he moves. Such information would include the nature of the path (hills, surface characteristics, irregularities in the terrain, etc.) and the nature of the obstacles and landmarks.

Further, as he progresses along his course, this visual map is continually updated and reviewed. Ongoing, and up-to-date information about the route and potential obstacles is also vital at night. However, the soldier is forced to rely greatly on non-visual cues, such as cognitive, and self-produced movement cues.

2. Perceptual Skills in Night Navigation.

a. Conceptual Factors. Most people have little trouble in navigating in familiar surroundings that are easily visible. Navigating at night and in unfamiliar terrain is a different matter. People frequently get lost, as there are few sensory cues to give them reliable information. When people are lost, the sense of isolation is increased.

Lost people first have to use many different sorts of cues to build up a "cognitive" map or schema of the terrain and then to know where they are with respect to the cognitive map. This ability is of fundamental importance, yet little is known about the sensory mechanisms involved in spatial cognition.

As a graphic example of the value of cognitive maps, consider the 1970 "Apollo 14" moon walk. Astronauts Shepard and Mitchell were within 75 feet of their objective, the rim of Cone Crater, but returned to Antares without completing their mission. The reason? They had become confused and disoriented by the lack of distinctive lunar landscape features and the endless sequence of gullies. It was only later that they realized just how close they had been to their objective.

At first sight, human beings appear poorer at navigation than many animals. Human beings, for example, lack a magnetic sense as far as is known, have no innate ability to use the sun and stars for navigation, and are relatively poor at finding their way home from strange places.

However, human beings have a great capacity for learning and utilizing important cognitive abilities. Cognitive abilities include the mental representation of geographic space comprising both the perception of spatial relations among external terrain features, and the perception which the individual has as he relates to those features in space. Those cognitive factors which appear most important for day or night navigation include map interpretation, terrain analysis, and the cognitive map or "schema" taken from memory. That is, important details of the terrain, as shown on a map, can be reconstructed in memory; the individual can then proceed to use this schema in various ways.

The soldier can compare the schema to the terrain he sees in order to know where he is; he can engage in vicarious manipulations or locomotions to know which way he has to go. He can try out the results of particular forms of behavior, the various approaches and paths, before committing himself to them in actual practice. At night, when the navigator does not have a ready view of a map, the schema may serve as an effective replacement.

It is clear that even a simple path cannot be followed blindly without some idea of its spatial relations to other objects. In practice, following a path must be supplemented by some sort of cognitive map in which the path is perceived in spatial relation to the other paths and terrain features.

Furthermore, the cognitive map functions to enable recall of landmarks and other topographical clues, and to improve the ability to recognize a landscape when viewed from a new angle. A cognitive map includes all sorts of memories of terrain features: visual memories, which are usually most prominent, motor and auditory memories, and memories of the details of maps.

A topographical map is, in fact, a graphical representation of such a schema and is the one most often used to develop and maintain a three-dimensional image of an area. Thus, the ability to read a map, and its careful study prior to any night operation, becomes an important element in successful night navigation.

What is often called a "sense of direction" appears to be a skill in developing a cognitive map of an area and up-dating the schema as one moves over the terrain. People vary greatly in this ability. The source of this variation is not yet known. Attention to cognitive skills, their evolution, and their individual variations should assist Army night mobility and night operations capability greatly.

b. Movement Factors. Successful mobility involves a number of component skills: There is the ability to travel in a straight line. People lost at night commonly veer or walk in a complete circle. Other successful abilities would be to maintain a "sense of direction" (maintaining a route); to detect variations in the terrain (e.g., slope, curvature, texture) one is traveling over; and to maintain time and distance (pacing).

To what extent these various abilities are correlated is not known. The sensory basis of these abilities is also unknown. Nevertheless, the skills require the individual to possess information regarding his change in position in space; in other words, that he have some appreciation of his active movements.

At night, the poverty of man's directional sense becomes obvious. Movement at night, particularly through forest country, is much like wandering through a maze. The trees and hills often conform to no sensible pattern. In such situations, people tend to veer or circle.

The bodily cues - presumably based on the tactile, kinesthetic, and vestibular senses - are inadequate to detect small changes in direction: a slight bias in the sensory system is sufficient to produce veering over short distances.

Most investigators claim that people veer to the right rather than the left, particularly when on foot. One theory of veering is that it is due to asymmetrical limb length, or asymmetrical muscular strength. However, it is hard to see how body asymmetry could also cause veering when driving a vehicle.

Blindfolded passengers in a car will often feel that the vehicle is following a curved path when it is actually going straight, and vice versa. The cause of veering is probably not any structural asymmetry, but some imbalance in the vestibular or kinesthetic systems. Clearly, then, any training in night navigation requires that each individual soldier, whether walking or riding in a tank, be apprised of the veering tendency in order to acquire compensating behavior.

Some aspects of night operations may depend on use of motorized vehicles (e.g., tanks, motorized armor, etc.). This raises additional problems for navigation, particularly since navigational aids, such as a compass, are not readily available.

For example, where troops are conveyed by vehicle, one element of information seemingly important in navigation is removed; that is, self-produced motion cues which are always available to the walking soldier.

Held and Rekosh (1963) have demonstrated that active movement interacting with a spatial environment is necessary for correct perception, for experiencing the world "as it really is."

More to the point, research at the Army Research Institute has demonstrated that the absence of active movement cues results in serious distortions in direction-finding behavior. The implication for military night operations is clear: if active movement is essential for maintaining accurate orientation, then the mobility of tanks, as one example, is severely reduced at night when visual cues are absent and navigational aids are unavailable.

Dead reckoning depends on estimating not only direction but distance traveled. One is lost if he loses track of either direction or distance covered, unless he meets another familiar landmark. Though primitive, the method can be more useful than a map or compass. For example, when lost at night, one may not be able to pinpoint his location on a map; therefore, he may not know which compass bearing to take. In such circumstances, one has to rely on dead reckoning.

Successful navigation by dead reckoning involves three stages: (1) setting out in the appropriate direction; (2) holding a steady course, keeping a running estimate of position, and checking expected landmarks along the way; (3) locating the destination and homing in on it. Problems of directional navigation will be covered later; but the problem of distance raises further questions of time and speed.

The apparent distance travelled is distorted by many factors which alter the apparent speed of travel or the apparent time taken: a decrease in apparent speed or an increase in apparent time makes the distance seem longer. Real changes in speed or time have similar effects, presumably because people miscalculate at least one of the factors.

Thus a distance seems longer when walked rather than run. It may also seem longer if great effort is involved, or if the route is new, or if the walker is tired or anxious. However, this subject is confused and contradictory, and it is easy to cite conflicting cases.

Experimental evidence is meager and often confusing. One source of confusion is the difference between the methods of reproduction and estimation. In the former method, the individual attempts to travel a given distance, e.g., "go 200 meters." In the latter methods, the individual attempts to estimate the distance traveled.

Ordinarily, estimation is a requirement of the navigator. Reproduction may be what is required of a reconnaissance patrol. Logically, the two methods should give equivalent results with overestimation in one method meaning the same as underestimation in the other. Psychologically, the methods may not be the same. Estimating a distance already traversed is not the same as striking out into the unknown for a given distance.

For example, people may overestimate the distance covered in the dark, yet also walk too far when asked to reproduce a given distance. Several experiments would be both interesting and important to carry out in determining the extent of distance errors for different terrain

features, different speeds of travel, various loads and, finally, the distance and/or time of travel least sensitive to error. Quantitative data of this sort can help in both training and in planning operations.

c. Sensory Factors. In discussing the behavioral problems in night movement, one should not overlook the range and number of sensory modalities through which spatial information is acquired. Equally significant is the integrative nature by which sensory information is related to spatial information.

The visual, tactile, olfactory, auditory, and kinesthetic sense modalities combine to give an integrated representation of any spatial environment. The modalities are complementary even though visual information predominates. For example, the distinctiveness or memorableness of a particular spatial environment is not solely the result of the way the environment looks.

Some blind people remember the various paths they traverse by the different feel of each path. The blind can become expert at following new as well as familiar routes, by using maps which rely on touch. While many such devices help the blind to detect obstacles and navigate, large-scale navigation demands some type of visual map, at least initially, and some residual vision which gives information and instructions about landmarks farther afield.

The significance of tactile or even auditory cues as night navigation aids remains purely conjectural. Significance of night vision capability in successful mobility is poorly understood. Little is known about how to utilize the residual vision available at night for night mobility. Although generally reported that night vision plays little, if any, role when navigating at night, residual vision may still provide useful cues.

Residual vision may provide direct visual information to avoid obstacles, and may be useful in organizing the non-visual abilities. The non-visual cues and the way they relate to mobility are not simple. No matter how limited, a visual reference can provide an organizational structure for auditory, tactile, and cognitive spatial information.

Continuous use of residual visual information may serve to establish and maintain the visual and non-visual spatial organization important for navigating at night; i.e., when most dominant visual cues are unavailable.

3. Directional Orientation to a Heading.

The most reliable guide to a heading is the compass. The standard Army lensatic compass is the major direction finder used by the infantry soldier for land navigation. The instrument has been found extremely versatile as it can be used many ways by manipulating its component parts.

Nevertheless, the lensatic compass has a number of serious deficiencies during night operations. For example, the dial is often not luminous enough for accurate reading at night. The legibility of the compass rose is poor and hence the compass headings are both difficult to read and often are confused; an 8 often looks like a 6 and vice versa. Because the compass rose floats, the lensatic compass must be level for accurate reading. However, with poor visibility at night it becomes very difficult to hold the compass level in the absence of visual feedback.

Although deficiencies of the lensatic compass have been consistently reported from the field, data is lacking to document them. Further, no data is available to determine requirements for a more effective night compass. Finally, no data shows comparative advantages of one compass over the other. Since dead reckoning may be the only effective means of navigation at night, it becomes important that the soldier have an effective and workable compass.

The second most reliable guide to direction, after the compass, is the sun, moon, and stars. Use of celestial cues is not instinctive, but can be learned with little effort. Most, if not all, people know the sun rises in the east and sets in the west. For greater accuracy, it is necessary to know latitude and time of year, and to consult a suitable set of tables. For ordinary navigational purposes, a low degree of accuracy may be quite acceptable, since the soldier can use other cues to guide him.

The moon is more complicated to use than the sun, since it rises and sets 50 minutes later each night. However, the illuminated part of its surface always points toward the sun, even when the latter is below the horizon. Therefore, it is always possible to take a bearing from the assumed position of the sun at the relevant time of night.

Stars are a simpler guide than the moon; stars can be used independently of time or season to locate the celestial poles. People all over the world recognize much the same groups of stars, though the same constellations bear different names. Regardless of names, many people know that the constellations rise in the east and set in the west, appearing to revolve counter-clockwise around the celestial North Pole, and clockwise around the celestial South Pole.

Stars reach the same position in the sky four minutes earlier each night; given sufficient charts or a good memory, it is possible to know the bearing of any star at any date, time, and place. Yet celestial navigation of even the most elementary sort is absent from most Army training programs in land navigation.

Navigators do not always travel in a straight line. Sometimes they make deliberate angular errors to ensure that when they meet a road or river they will know whether to follow it to the left or right to reach a landmark. Navigation of this sort involves ability to judge angles. There seems to be little direct, experimental evidence on angular errors during bodily turns.

Triangle-completion tests - ability to return to starting position when blindfolded after following two sides of a triangle - give ambiguous results, because both angular and distance errors may be involved.

Recent studies conducted at the Army Research Institute show that angular error increases with the size of the angle to be judged, up to and including a 90° turn. More likely, kinesthetic cues are more important than vestibular cues in this type of judgment. Vestibular-defective individuals, for example, perform as well as normal subjects when active movement is employed in making an angular judgment.

However, the vestibular-defective individuals are considerably worse than the normal subjects when passive movement is employed in making an angular judgment. The lesson is, of course, that vestibular-defective soldiers should not be asked to control the direction of vehicles when visual cues are not readily available to guide them.

Implications for Future Research.

The following problems may appear innocent enough, but the clearest answers lead only to more problems. Nevertheless, the most obvious problems that require attention are:

- Identification and investigation of individual differences in navigation.
- Study of structure, development, and acquisition of cognitive maps in geographic space perception.

It seems extremely likely that the three-dimensional image of "cognitive" maps is used not only to process current stimulus input, but also to process images taken from memory. That is, imaginary scenes can be reconstructed in space and then the individual can proceed to use this as geographical space in which to navigate.

Elucidation of cognitive cues is germane to understanding development and training of night mobility skills. Although research has established the general character of the three-dimensional cognitive schema, future research should include the following:

- Clarification of terrain features and spatial relations among the best remembered features in the individuals' schema.
- Determination of amount and kind of training, e.g., map reading or map interpretation, required to form an appropriate cognitive schema of a geographical area.
- Determination of the most useful aids (maps) in acquiring a cognitive schema.
- Determination of the geographical range in which the cognitive schema is functional and where it breaks down.

- Examination of any relationship between individual differences in navigation and differences in the individual's dependence upon his terrain schema.
- Investigation of differences between a terrain schema constructed from visual information, and a schema constructed from other modalities, such as tactile.
- Study of time and distance estimation as a function of type of terrain and carrying load.

C. Night Vision.

1. Many night military activities depend on the night vision capability of the individual soldier and on equipment that enhances this ability. In recent years, devices have been developed that improve vision at low light levels. However, efficient use of the devices depend on recognizing the limitations of the individual soldier's visual capabilities.

Because night vision is markedly affected by motivation, experience, training, and other behavioral factors, night vision is not synonymous with scotopic or mesopic sensitivity. Further, human capacity to see at night is notoriously inconsistent. Capacity depends on the individual's level of dark adaptation, but also includes other physiological and behavioral components.

The rate and final level of dark adaptation and ability to see at night show wide variation. Similarly, dark adaptation and scotopic and mesopic sensitivity vary with the individual over a period of time.

More importantly, the normal variation in night vision capability among individuals is sufficiently large to affect performance of military tasks carried out in darkness. Validity of this conclusion has not been firmly established; however, recent research on human factors in efficient use of night vision devices suggests relevancy of the conclusion to developing concepts of tactical capability.

Common knowledge confirms that every aspect of vision appears altered at night. Modifications in the appearance of the scene have a physical basis, for radiant energy is profoundly attenuated at night. With night vision, an object is less visible, its color and size seem different, and distance is often misjudged.

As a result of the loss of light energy at night, we would expect a minimum ability to resolve small details (resolution acuity), and a minimum ability to perceive differences in the relative distance of different objects (stereoacuity). This is not surprising, since most changes in physical conditions affect both forms of acuity in much the same way. Yet stereoacuity drops with decreasing illumination at a much greater rate than does resolution acuity (Luria and Kinney, 1968).

To explain stereoacuity at night, two aspects of the night scene, distinct from the scene at daylight, seem pertinent: the loss of target contrast produced by the decreasing illumination level, and the fact that there are few clearly visible objects. The scene appears hazy, lacks definition, and approaches what is known in psychology as a Ganzfeld, an unstructured, homogeneous field of view. The fact is well known that a Ganzfeld distorts many visual functions, impairs target detection, and degrades other processes considered basically foveal.

Apparently then, the typical loss of contrast, as well as the lack of peripheral stimulation in the night environment, causes a serious loss in stereoacuity. Important to stereoacuity is peripheral stimulation; this conforms to findings that individuals suffering from retinitis pigmentosa and a consequent loss of visual field down to a 10-degree visual angle also show a marked loss of stereopsis.

During military night operations, the question remains whether stereoacuity can be improved significantly by introducing clearly visible peripheral stimuli. e.g., signals, flares, and other forms of battlefield illumination.

The loss of light at night should also affect perception of size and distance of objects. Indeed, a common observation is that objects at night appear to be farther and, depending on distance, either smaller or larger than in actuality.

Further, distance overestimations increase as light level decreases. Military commanders, for example, report that it is common at night for a soldier to overshoot an observed target. The overestimation of distance stems partly from the loss of contrast at night; the overestimation probably is also a function of the Ganzfeld characteristics at night.

In short, both relative and absolute depth perception are less acute at night. Loss of contrast, which intensifies with the gathering darkness, and the typical lack of stimulation at night cause increasingly larger overestimations of distance.

Optical aberrations at night have been widely investigated (Byram, 1944). The effects of night myopia, for example, take on their greatest significance when the pupil of the eye is large, that is, when the field luminance is low. Night myopia, which accounts for significant blurring of objects up to an observation distance of approximately one meter, has to be a consideration when close visual work is required.

Generally speaking, the perception of size can be predicted fairly accurately from the perception of distance if other factors such as familiarity and context are controlled. For example, near objects appear larger in daylight than far objects of the same size. However, at night, when the same object appears to be farther, although optical image size

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has not changed, the apparent increase in distance is attributed by the individual to an increase in size. This conforms to the often common experience that objects loom in the dark, i.e., they appear larger than they really are.

On the other hand, size is underestimated at greater distances at night, as one would expect from the increasing attenuation of light with distance. Dim objects appear smaller than bright objects of the same size and at the same distance. Although it has been suggested that we naturally appraise darker objects as smaller than bright objects, no adequate explanation of this illusion has been offered.

The point where objects begin to appear smaller than they actually are depends upon both distance and available light. No quantitative assessment of this phenomena is available. Nevertheless, apparent distortions of size and distance at night are clearly relevant to the operational tasks of learning to sight, aim, locate, and acquire targets.

The perception of color is another aspect of night viewing of considerable importance. Since color is generally used either to enhance or camouflage an object, it is important to know which colors are most and least visible. The topic is covered adequately in a variety of texts and need not concern us here. Source material can be found in The Human Senses by F. Geldard, pp. 83-124, and Vision and Visual Perception (Ed., C. Graham), pp. 370-478.

Although responses to color targets as a function of illumination has been widely investigated, little consideration has been given to the study of fluorescent color. Fluorescent colors have, however, been extensively used to increase visibility of objects. Fluorescent colors convert short wavelength energy to which the eye is relatively insensitive into longer wavelength energy to which the eye is more sensitive.

The converted energy is added to whatever reflected light is available, thus increasing the visibility and contrast of the painted object. This is, of course, contingent upon the amount of short wavelength light available at night. Fluorescent paints introduce an interesting interaction: The exciting energy for fluorescence is in the shorter wavelengths of visible energy. These wavelengths are more easily scattered in the air than the longer wavelengths thus produced from the fluorescent surface.

The result is that relatively few short wavelengths reach the painted surface at night, making fluorescent surfaces visible, at best, at short distances. Nevertheless, there may be an advantage to maintaining some form of visible contact among troops at night over relatively short distances while remaining less visible over longer distances. No systematic effort has been made, as far as we know, to establish the utility of these principles for military night operations.

To summarize, visibility can be predicted from a knowledge of the spectral sensitivity of the eye and the spectral distribution of energy reaching it. To specify the spectral distribution, one must know four attributes. (1) the energy reaching the target, (2) the reflectance of the target, (3) the transmission characteristics of air, and (4) the background. From these values, both the visibility and color contrast can be calculated.

The Army has recently introduced a new family of optical aids e.g., image intensifiers, that improve visual acuity and pattern recognition under reduced levels of illumination. However, as already pointed out, efficient use of night vision devices depends on recognizing limitations of the visual capabilities of the individual soldier.

Surprisingly, very little quantitative data is available which provides a comparison of various forms of vision--normal and aided--as a function of light level, contrast, e.g., background and atmospheric, absolute and relative distance of targets, color, and whether the target is moving or stationary. Much qualitative data supports the advantages of night vision devices but little quantitative data relates information about human vision to the image enhancement characteristics of night vision devices.

Thus, the Army has no means of determining the limits of normal and aided vision under conditions which closely simulate operational conditions. Optimizing the utility of night vision devices obviously requires suitable quantitative information concerning effects of different parameters of image formation upon the soldier's ability to perceive the existence and properties of targets viewed through these devices.

2. Implications for Future Research

- a. An analysis of the requirements for night vision in specific military tasks of all types and the methods of selection of soldiers for these tasks.
- b. Review of procedures currently employed for testing dark adaptation and night vision in meeting military requirements for night vision capability.
- c. Study of the visual effects of drugs commonly administered to the soldier under combat conditions.
- d. Comprehensive review of the effects of many classes of drugs, and of smoking and alcohol on the visual capabilities of the soldier.

- e. Further examination of the suggested relationships between the use of tobacco and alcohol and the occurrence of amblyopia, decreased visual acuity, central scotoma for color, and loss of accommodation. The significance of frequency of smoking to dark adaptation measurements requires further study in relation to the military requirements of the soldier.
- f. Analysis of toxic elements, including carbon monoxide, hydrocarbons, and oxides of nitrogen as produced by vehicular traffic and various weapons, to ascertain the usual and maximal amount of exposure; and the study of the combined effects of these substances on dark adaptation and night vision.
- g. Study of the potential effects on dark adaptation and night vision of interaction of noxious environmental contaminants with military therapeutic drug regimens.
- h. Study of the influence of toxic environmental contaminants or therapeutic drugs on the effective use of optical aids by the soldier in reduced illumination.
- i. More extensive examination of the range of individual variation in dark adaptation and night vision, especially for soldiers with combat and field command responsibilities or special tasks.
- j. Investigation of the incidence and influence of astigmatism, accommodation defects, and other ophthalmologic defects on the night vision capability of the soldier.
- k. Analysis of the value of training individuals for night vision capability, recognition of individuals with inadequate or superior night vision capabilities, and assignment of military duties to the best qualified men, which would lead to more efficient use of night vision devices.
- l. Investigation of the utility of providing light stimulation on the periphery of the battlefield to enhance the perception of relative and absolute distance.
- m. Study of the utility of fluorescent colors for enhancing the visibility of objects at night.

D. Fatigue.

1. The efficiency of the individual soldier participating in extended military operations, both day and night, depends very much on his ability to resist and recover from the effects of fatigue due to prolonged operations. The whole pattern of performance decrement and recovery from fatigue may be envisaged as that of a system having a limited capacity for continuous operation and some reserve that can be used to deal with temporary additional requirements. Rest allows the reserve to be re-established.

It must be emphasized, however, that such a conceptual model, though convenient, is not true in a literal sense. In almost any given instance, the effects of fatigue upon performance depend markedly on the soldier's motivation, his skills and knowledge of the job, his state of health and fitness, the nature of the task to be performed, and the organizational and physical aspects of the operational environment. Further, the significance of these variables is not completely understood as they relate to the effects of fatigue.

Knowledge about effects of fatigue on performance is made even more complex because we have neither a standard means of classifying the military tasks or operational environments, nor a standard system for quantifying the human performance requirements related to them. Equivalence of knowledge gained from laboratory and field studies to the operational environment is not at all firmly established.

However, one may tentatively suggest that currently available knowledge may still be useful as guidelines for commanders who are responsible for planning military operations and unit organization, e.g., manning levels, reserve strength.

Summaries of work on fatigue have been provided by several authors (Allusi, 1969; Wilkinson, 1966; Woodward and Nelson, 1974). The subject will be discussed relatively briefly here, first re-examining the effects of fatigue on performance, and then going on to work-rest schedules and recovery from fatigue. Generally speaking, four main types of behavior change come about from fatigue: perceptual changes, slowing, irregularity of performance, and disorganization of performance.

a. Effects of Fatigue. The effects of fatigue on performance vary widely from essentially none to an almost complete breakdown in performance. Effects are, of course, a function of many factors, including the individual's ability to resist and recover from fatigue, the time of day, and the duration and character of the work being performed.

Within broad limits, the crucial variable in predicting the extent to which fatigue will affect performance is the factor of motivation. This finding is important, as showing that fatigue effects are to a large extent under voluntary control, in the sense, perhaps, that the individual sets a level of effort he is willing to make and of discomfort he is prepared to bear.

For example, the impact of fatigue certainly is less pronounced when the consequences of performance entail profound alterations in the saving or loss of life, and less pronounced when the tasks are sufficiently complex and attention-demanding to be "interesting."

Physical activities generally are less likely to show performance decrements than mental activity. Well-learned skills are less likely to suffer from the effects of fatigue than newly learned skills. This suggests, of course, that to minimize fatigue effects, the individual soldier should be well-trained and experienced in the tasks he will be expected to perform.

Although it is obvious that some kind of fatigue effect occurs with increasing time on a task, the following factors, perhaps, are not obvious. First, if given the opportunity, individuals tend to distribute their efforts over the period of activity so as to minimize fatigue effects, adjusting their pace to the expected duration of activity, working fast if the duration is to be short, slower if it is to be long. This means that fatigue effects are more likely to show if the individual soldier has to work under pressure for an unknown period than if he works at his own pace or for a time known in advance.

Secondly, fatigue effects tend to be specific to the activities that produce them, leaving other activities little if at all affected. As a consequence, a soldier who is taken off his main job can be assigned, for brief periods at least, to another activity with little decrement in performance. However, motivational effects may explain sufficiently the changes in performance occurring during a shift in activity.

Finally, fatigue effects tend to be cyclic, with worst performance occurring in the early morning hours. Presumably these cyclic effects arise from physiological rhythms over a 24-hour period, and from physiological changes related to time from last meal. In this connection, studies have found that rest-breaks are more effective if food or refreshments were taken.

As noted earlier, individuals differ widely in terms of resistance to fatigue effects. Investigators have attempted with little success to relate these differences to standardized measures of personality and intelligence.

There is some indication, however, that fatigue has a negative effect on an individual's mood or disposition, as evidenced by reports of increased hostility, irritability and depression. Subjectively, such states of mind seem to arise from long-continued activity (generally, beyond 36 hours continuous work) leading to mild chronic overtenseness. In severe forms, such states of mind seem to be the effects of chronic stress, and can lead to an inability to concentrate or make decisions, and to feelings of futility. Some of these effects appear coupled with low morale and poor attitude, and thus with various factors concerning social and physical organization, such as type of leadership and feedback about one's performance.

b. Work-Rest Cycles. Much interest in fatigue research has been directed to determining the work-rest cycle most effective for reducing the effects of acute and chronic sleep loss. One problem has been that activities during work and rest have rarely been specified. Only recently has the relevance of resting activity for working performance been recognized. It may make a difference, for example, if the rest period is devoted to sleeping, reading, or engaging in athletic activity. It should be equally clear that the nature of the work activity is an important variable and must be considered in establishing a work-rest schedule.

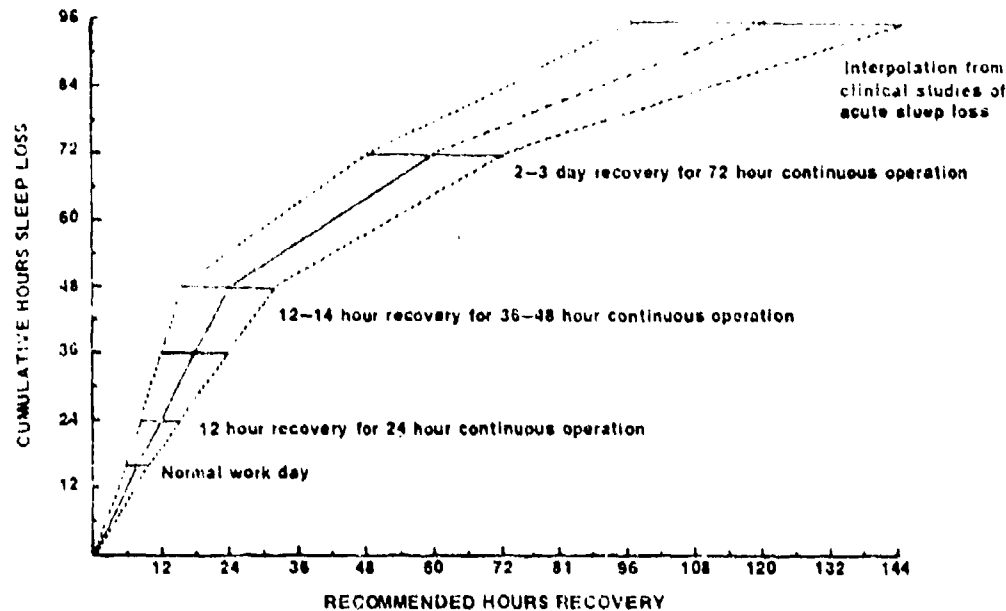
Summaries by Woodward and Nelson (1974) show that some qualitative assessments of certain work-rest cycles can be made on the basis of available data. They report, for example, that for a period up to two weeks, performance appears to be little affected by the type of work-rest cycle as long as no period of acute sleep loss is experienced. For periods longer than two weeks or under stressful conditions, the hours of rest relative to work become more critical.

Adaptation to atypical work-rest schedules generally require a 3-4 week period. To adapt, although incompletely, from a typical day-night cycle to one where the soldier must operate at night should require a period of 3 to 5 days. Woodward and Nelson (1974) also report evidence which suggests that stable work-rest cycles result in better performance than when the cycle is rotated.

Further, if the cycle is stabilized, performance appears to be as good at night as during the day. Evidence also indicates individual preferences among individuals for night or day work shifts. This evidence would emphasize the importance of identifying individuals with known preferences and using the data in making appropriate assignments.

c. Recovery from Fatigue. The problems of recovery have not been explored nearly as extensively as those of fatigue effects and work-rest cycles. A few generalizations are valid, nevertheless. Recovery of performance from acute sleep loss up to 48 hours has been widely reported as generally complete after 12 hours of rest, although subjective fatigue is reported until after the third full night of sleep. Sleep loss of more than 48 hours will require more than one full night of sleep before performance recovery is complete. Figure 1 shows the recommended hours recovery as a function of cumulative hours sleep loss.

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Summary: As cumulative hours sleep loss increases, so does ratio of hours recovery/hours sleep loss (and its variability as a function of individual/situational differences) (From Woodward and Nelson, 1974).

Figure 1. Recommended hours recovery as a function of sleep loss.

On the basis of available data, as well as common sense, it is reasonable to suppose that if a man has endured a stressful period of sleep loss, he must be allowed adequate sleep, unless one is prepared to accept very low performance efficiency.

Stimulant drugs may obviate some of the decrements in performance associated with sleep loss. D-amphetamine is probably the most powerful stimulant drug used. While stimulants undoubtedly have an arousing effect, their use has serious drawbacks. For example, responses to stimulants are highly individual and dose-dependent. Thus, mass administration of stimulants, or prolonged or frequently repeated usage cannot be recommended in the absence of detailed information on individual variability to drug effects.

2. Implications for Future Research. The following suggestions for future research are presented as major areas where work is still needed. Most of the material described here was taken directly from published reports with minimum modification or elaboration. This is not to say we have exhausted all major avenues for future research. We have not.

- Investigation of the extent to which napping or prone-position resting enhances performance during sustained operations.
- Controlled studies on the influence on sustained performance capability of level of energy expenditure during continuous activity.
- Investigation of the extent to which sustained-performance capabilities are influenced by physiological (circadian) rhythm.
- Elucidation of the "total costs" to the human system of conducting sustained operations.
- Continued studies on the maximum length of time man can conduct sustained operations under optimum and minimal conditions.
- Study of the minimum amount of sleep required for performance, physiological, and psychological recovery following sustained operations.
- Study of the extent to which recovery functions interact with physiological rhythms.
- Examination of the extent to which recovery functions are influenced by factors in the environment that influence sleep quality.
- Further examination of the relation between recovery functions and the "costs" expended during previous sustained operations.
- Examination of the extent to which results from laboratory studies, field experiments, and full-scale field tests can be generalized to the operational situation.
- Analysis of critical individual factors (i.e., age, sex, personality variables, and sleep requirements) important to man's ability to conduct sustained operations.
- Study of the extent to which drugs, scheduling, selection, and training can be employed to enhance man's continuous-work and recovery capabilities.

- Determination of whether individuals habituate to prolonged and repeated work-rest cycles. If so, how long does it take for habituation to occur, and how long does habituation persist after resumption of the normal 24-hour cycle?
- Study of the interaction of the effects of sleep loss and work-rest schedules with interpersonal behavior and group or team performance.

E. Psychological Stress.

1. Introduction. An understanding of the effect of psychological stress upon skilled performance is of great practical importance for the military. Soldiers often must perform skilled tasks under highly stressful conditions. Such is obviously the case in combat, becoming more intense during night combat activities. Reduced vision, a greater sense of isolation, the increased likelihood of becoming lost and disoriented, are all characteristically part of the military night operation scene.

Under these conditions effectiveness of the individual soldier must be maintained even when he is operating in the dark, isolated, disoriented, and threatened by physical injury. The fact that the soldier often may be required to work under stressful conditions, particularly at night, needs no further elaboration.

The problem of psychological stress involves the problem of definition. It is not possible to think of psychological stress except as an inference from external and/or internal manipulations of either the environment or from measurements of change in behavior.

On the environmental side, the term has been used to describe situations characterized as new, intense, rapidly changing, and sudden or unexpected. At the same time, isolation, highly persistent stimulation, and fatiguing and boring settings, among others, have also been described as stressful, as have situations susceptible to hallucination and leading to misperception which often occurs at night.

On the behavioral side, the presence of emotional activity has been used post facto to define the existence of stress. Indices used include such overt emotional responses as tremors, stuttering, exaggerated speech characteristics and loss of sphincter control, or such performance shifts as slowness, erratic or disorganized performance, malcoordination, and perseverative behaviors. Clearly wide variations exist in specific uses, specific definitions, and specific purposes with which the term "stress" has been associated.

Marked individual differences further complicate the problem of psychological stress and performance, in that all individuals do not respond to "stressful" environmental conditions in the same way.

This has been shown when the conditions studied were combat, threat to life, internment, threat to status, and others. It is reasonable to say that no situation is a stressor to all individuals exposed to it. Earlier assumptions of a common all-or-none psychological stress state are untenable in the face of evidence to the contrary.

Hence, the effects of stress on performance are not general but will depend, for example, upon significant events in the individual's life, what the individual expects or demands of himself, and how he may perceive or appraise a threat. In all these instances, we see an emphasis on individual determinations of when stress will or will not occur.

Stress appears to be a behavioral state and its induction appears to depend on the mediation of some appraising, perceiving, or interpreting mechanism. Clearly, certain universally adequate stimuli may be expected to lead to stress more rapidly than others, such as extreme and sudden life-threatening situations. This should lead to a stress state in all persons, with little variation in the rate of development.

However, less severe situations will give rise to behaviors that vary greatly from person to person. Such situations may induce anxiety or stress much more rapidly in one person than in another. This is particularly so where stress-producing characteristics depend on prior learning, as in fear of the dark.

Doubt exists that there is such a thing as a general stress tolerance in individuals. More likely, a person carries a greater or lesser insulation from the effects of certain kinds of stressors rather than from others. The common idea of a threshold of tolerance for stress implies that stressors must reach a given intensity in order to arouse stress.

Thresholds differ, apparently, depending on the kinds of threats that are encountered. Probably, individuals are differentially vulnerable to different types of stressors. In other words, not only must a situation be of a given intensity to lead to stress; it must be also a given kind of situation for a particular person. To know what environmental conditions are likely to lead to stress for a particular individual, the individual's motivational structure and prior history should be taken into account.

Where the particular motives are known, a reasonable prediction of stress likelihood of the individual soldier might be made. The motives might be:

- what an individual holds important and not important,
- what kinds of goals he will work for and why, or
- what kinds of situations have for him been likely to increase fear, or lead to defensive behaviors or escape.

The fulfillment of this aim is, indeed, no simple affair. For the military, it is clearly impractical.

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In addition to emphasizing the role of the individual in producing or reducing stress, attention must also be given to organizational factors pertinent to the military situation. The influence of one's peers and the military milieu significantly affect stress reaction. The role of encouragement and that nebulous influence called leadership further extend the list of factors related to psychological stress and performance.

It is further evident from the meager data available what some of the factors are which can influence the quality of the individual soldier's ability to adjust to, tolerate, or master stress. Factors may include:

the nature of the individual's early identifications and his present character structure;

his ability to master strong and disturbing emotional tensions;

the extent to which he knows about all aspects of the (military) situation, so that he is not helplessly unaware of the nature and source of the military threat; the extent to which he can control, or believes he can control, stress-producing events in order to reduce feelings of helplessness;

his available skills and other means of dealing effectively with the threat;

the strength and pattern of his motivation;

the leadership necessary to instill a feeling of belonging and an attitude of pride;

the presence of demanding tasks which distract attention away from stress-producing events;

and the degree to which the individual perceives himself as occupying a significant military role in a clearly delineated group which imputes explicit status to that role (Torrance, 1961).

If one tries to gain some overall perspective on what the stress data reveal so far of relevance to the Army, one is led to the following general observations:

- a. Different individuals respond to the same stressful conditions in different ways. Some enter rapidly into a stress state; others show increased alertness and apparently improved performance; still others appear immune to stress-producing qualities of environmental conditions.
- b. The same individuals may enter into a stress state in response to one presumably stressful condition and not to another.

- c. Consistent intra-individual response patterns occur in stress situations. The notion of a common stress response needs to be re-evaluated.
- d. A great variety of different environmental conditions can produce stress.
- e. Behaviors resulting from a stressful situation may be alike or different, depending on the context of the situation and how it is perceived.
- f. The intensity and extent of the stress reaction and associated behaviors may not be readily predicted from a knowledge of the stressful condition alone, but require an analysis of underlying motivation patterns and of the context in which the stress is experienced.
- g. Psychological stress probably is best conceived as a state of the individual under extenuating circumstances rather than as an event in the environment.

2. Implications for Future Research.

It should be clear from the foregoing that we are still a long way from having answers to all the questions on the effect of psychological stress on performance. It would be presumptuous even to suggest that we know the right questions to ask, or that we have the techniques and methodologies in the laboratory and field to provide all the needed meaningful answers. The following questions for future research are presented, however, as the most obvious for military application.

- What is the relationship of personality variables and past history with performance under stress? Very little information has been obtained about the relationship between various measures of personality and reaction to stress. It would be most useful to be able to predict which soldier(s) will be adversely affected by a stressful situation.
- What is the relation between the intellectual and emotional capacity of the soldier and his reaction to stress?
- What aspects of particular military tasks are most vulnerable to psychological stress, e.g., decisionmaking, perceptual motor skills, information processing, memory, attention, etc.?
- What activities and what training will best enable the soldier to cope with stressful situations?
- What relation do emotion and motivation have to performance under stress?

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